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MAY 21, 1984 THE JOURNAL OF TELECOMMUNICATIONS SINCE 1901

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May 21, 1984

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No. 21

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Published by TELEPHONY PUBLISHING CORP., 55 E. Jackson, Chicago, IL 60604
Telephone 312/922-2435; TWX 910 221 1058

European Bureau, 136 Broomfield Rd., Chelmsford, Essex CM1 1RN, England; Telephone Chelmsford (0245) 58257; Telex 995801 GLOTLX-G.

TELEPHONY (ISSN 0040-2656/83-0 a$1.50) is published weekly (except twice weekly during the second week of August and three times during the month of December) by Telephony Publishing Corp. Officers of Telephony Publishing Corp. are Dan S. Fargo, President; Leo Anderson, Executive Vice President; Del Myers, Robert Wehofer and Janice R. Drummond, Vice Presidents. Postmaster: Please send form 3579 to Subscription Dept. TELEPHONY, 55 E. Jackson Blvd., Chicago, IL 60604. Second class postage paid at Chicago, Ill., and at additional mailing offices. Single copies (payable in advance) U.S. $3.00 ea. Outside U.S. add $1.00 ea. Subscriptions: $30 one year. Outside U.S. $56 per year. Subscription rates apply to employes of operating telephone companies; telephone consultants; contractors; interconnect companies; specialized common carriers; military government associations; private communications users; schools; libraries. All others $36 one year. Outside U.S. $62 per year. Change of address: include old address as well as new address. Attach issue label if possible. Allow 4 weeks for change to become effective. Copyright 1984 by Telephony Publishing Corp. Permission to photocopy for internal or personal use or the internal or personal use of specific clients is granted by Telephony Publishing Corp. for libraries and other users registered with the Copyright Clearance Center (CCC) provided that the fee of $1.50 per page is paid directly to CCC, 21 Congress St., Salem, MA 01970. Special requests should be addressed to Telephony Publishing Corp.

Is there a satellite in Korea's future?

EITEL M. RIZZONI and DONALD K. DEMENT

AT THE REQUEST of the Government of the Republic of Korea, Teleconsult Inc. has done a feasibility study on the construction of a satellite system that would be integrated with the national telecommunications system.

There are five separate major functions required of the satellite system: four communications networks; two video relay and television community-service channels; three direct broadcast channels, remote sensing; and satellite protection and system security. These represent a diverse set, and result in a design for a hybrid-service system. Networks are varied. A 2000-circuit requirement for telephone traffic and a 1000-trunk data communications network is required between major-city nodes. A separate 200-circuit network is required for 20 remote islands. Data requirements for a wide range of services, including a variety of systems for flood warning, meteorological data, railroad information and power plant data control, have been addressed by a special network. Finally, approximately 50 mobile/transportable terminals will be employed, with an 800-circuit requirement.

'As projected from 1983 to 1986 needs, total terrestrial telecommunications in Korea is growing, and is expected to continue growing for the next decade, at a rate of 30% each year.'

As projected from 1983 to 1986 needs, total terrestrial telecommunications in Korea is growing, and is expected to continue growing for the next decade, at a rate of 30% each year. Based on these rapid increases and future demands, a spacecraft and earth terminal design has been developed that will provide three to four times more circuits than are presently needed. This growth factor can be accommodated with little cost to the spacecraft. The earth terminal system then can grow as needs arise.

Two types of television service have been requested, one for community reception and subsequent redistribution, and the other for direct reception to individual homes and businesses. An implicit requirement is the ability to distribute domestic TV coverage of the 1988 Olympic Games, which will be held in Seoul, and to interconnect that coverage with worldwide retransmission facilities.

The community distribution is designed for two satellite transponders, and a third may be implemented. The video relay need is satisfied by remote feeder service using fixed-service transponders to a

Eitel M. Rizzoni is President and *Donald K. Dement* is Vice President for Satellite Systems at Teleconsult Inc., Washington. This article has been adapted from a paper presented Aug. 5, 1983, at the World Communication Year '83 (WCY '83) International Telecommunications Forum in Seoul, Korea. The authors also would like to acknowledge the contributions of Willis DeHart, Frank Mulholland, John Tatlock, Peter McManamon and Linda Bower.

Table 1
Cost comparison of the three options
Korean satellite system, lease from INTELSAT and terrestrial system
($ Millions)

	Investment Year	System Operation Year 1	2	3	4	5	6	7	Total over period
Korean Satellite System									
Capital Cost	257.4	—	—	—	—	—	—	—	
Annual Operating Cost	—	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Total	257.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	292.4
							Less: Unused capacity		- 134.7
									157.7
Lease Capacity from INTELSAT									
Capital Cost	42.7	—	—	—	—	—	—	—	
Annual Operation Cost	—	36.1	36.1	36.1	36.1	36.1	36.1	36.1	
Total	42.7	36.1	36.1	36.1	36.1	36.1	36.1	36.1	295.4
Terrestrial System									
Capital Cost	53.6	—	—	—	—	—	—	—	
Annual Operating Cost	—	5.4	5.4	5.4	5.4	5.4	5.4	5.4	
Total	53.6	5.4	5.4	5.4	5.4	5.4	5.4	5.4	91.4

central broadcast and monitoring facility in Seoul.

The dominant requirement is for direct broadcast service. This prerequisite dictates the need for three separate transponders.

An objective of the broadcast service capabilities of the spacecraft is to send to nearly 100% of all household's the current four channels of national television coverage. A mix of direct broadcast earth terminals together with community service earth terminals feeding low-power rebroadcast stations is recommended.

The radio regulations of the International Telecommunication Union (ITU) assign to Korea an orbital location for broadcast satellite service (BSS) at 110° east longitude, using direct polarization with even-numbered channels from 2 to 12. Using a slightly modified coverage area, the fixed satellite service (FSS) channels can be operated advantageously from the same spacecraft. The approval of an application for the use of this position must be obtained from the International Frequency Review Board as early as possible to receive assurance of use and coordination rights.

A shared FSS/BSS band with a relatively high power flux density (PFD) -111 dBW/m^2 is also assigned between 12.5 and 12.75 gigahertz (GHz). While it is required not to interfere with the systems of other countries, which limits PFD outside Korea, this requirement can be met with a relatively fast roll-off of antenna patterns.

Coordination with Japan in regard to the earth terminals to be used with the BS-2 spacecraft (which was launched in January, is co-located at 110° east and operates on channels 11 and 15) should be of minimal difficulty because of opposite polarization sense and the use of different channels.

This high PFD limit requires of the satellite only a modest transmitter power because of its antenna's beamforming and high gain. Together, they bring to the earth terminal system the advantages of relatively small size and modest receiver noise performance requirements, which will minimize the earth segment costs and permit wide proliferation of Korean satellite broadcast receiver systems.

The requirement for special data circuits for remote sensing would be accomplished by the use of an ultra-high frequency (UHF) receiver on the spacecraft. The relay of ground-sensed events is practical by using small, unattended earth terminals that periodically burst small data packets to the satellite on a UHF band allocated for meteorological aids. The satellite would relay these data on an FSS downlink channel to a central location for processing and redistribution. This system has been in use elsewhere in sensing a wide range of environmental conditions such as floods, fires, weather situations and other parameters. It can be accommodated in the design at very modest cost.

Because of the desire to implement the satellite system before 1988, only existing basic spacecraft designs and only those with known approximate cost and performance parameters and histories of good performance in orbit were considered in the feasibility study. The satelllite's communications performance, antenna coverage-area design and its size, mass estimates, launch availability, minimized costs and other factors, have led to the recommendation of a "Delta-sized" satellite. Reservation contracts and other arrangements must be made soon for a suggested launch not later than the winter of 1987.

The spacecraft's half-power antenna coverage pattern would include a considerable portion of Japan and North Korea. The broadcast transponder system, if chosen to provide effective isotropic radiated power (EIRP) of 59.5 dbW at the half-power beam edge, meets the PFD limit of minus 103 dbW/m2. The resulting traveling wave tube (TWT) transmitters would be required to furnish 60 W each. Using known and available 100 W TWTs operated at 60 W, the three operational broadcast TWTs together would demand about 750 watts of direct current (dc) power. For known spacecraft designs, this permits seven to eight transponders for fixed-service operation, in addition to the five to six broadcast channels. However, the power radiated outside the desired area is not useful—no other lower-priority functions can be served—and this is not a conservative dc power design for this early, conceptual stage.

An alternative, "largest-antenna" approach was also considered. Using an 84-in. shroud limit, the maximum-sized, circular, symmetrical antenna would provide a half-power beam width of 0.824° at 11.7 GHz. Its gain of

Continued on page 40

46.1 dBi leads to the use of 30 W TWTs for BSS and 16 5-W TWTs for the FSS. This permits the three DBS channels and the two video relay channels in the BSS band, plus 16 FSS transponders, to be operated with dc power margin remaining. The pattern, however, is restricted so that the major Korean islands are not covered, and the sharp pattern-edge roll-off would be noticeable in the case of any spacecraft motion from natural disturbances or maneuvers.

A third design using an elliptically-shaped, fast roll-off pattern reflector solves these problems, while still fitting the desired shroud limits. As shown in Figure 1, the elliptical pattern results in better island coverage of 1.2° by 0.8°. The resulting broadcast system, using three 40 W TWTs requiring 300 W dc, three 10 W TWTs for the video distribution system, and the 16 FSS transponders using 5 W TWTs, would require a total of less than 500 watts. This is suitable for the use of existing spacecraft buses.

A Ku-band frequency plan has been proposed. The 16 FSS transponders would occupy the full 12.5 to 12.75 GHz band, using a cross-polarized feed system to provide for frequency re-use in 27 megahertz (MHz) channels. The 27 MHz transponder bandwidth is optimal for the use of medium-speed time-division multiple access (TDMA) at 45 megabits per second (Mb/s). With additional ground-based equipment, expansion to 90 Mb/s service is possible. Land mobile satellite service is permitted in the recommended uplink band—14.0 GHz to 14.5 GHz—and can operate with small and low-cost antennas.

The uplink parameters were selected to be 14.0 GHz to 14.5 GHz for the FSS, and 14.5 GHz to 14.8 GHz for the BSS. A millimeter-wave command system is recommended, with processing (encryption, spread spectrum) as required. The total band occupancy of both services is only 460 MHz, which makes possible the unification of earth terminal transmitter design. An optional cross-strap of transponders between three FSS channels and three community television channels would permit transmission from the satellite in the BSS band from any of the FSS terminals, as desired. In this way, the FSS stations can optionally be used to either relay events to a central uplink or to be designated for direct broadcast from their location without an additional DBS transmitter.

A design for an inter-city network was made based on information about traffic furnished by Korean Electrotechnology and Telecommunications Research Institute (KETRI). The considerable expansion in capability of the spacecraft FSS will permit new traffic to be carried, as desired, with little concern for saturation of the spacecraft facilities for many years.

Using multiple-carrier FDM/FM/FDMA (frequency division multiplex/frequency modulation/frequency division multiple access), the 27 MHz transponders can handle 10 carriers each with about 1200 one-way trunks not using companding or time-assigned speech interpolation (TASI) techniques.

With companding, two transponders will satisfy the 4000-channel requirement, and permit expansion via ground facility installation of other compression techniques as future requirements dictate.

The 27 MHz transponder capacity for digital service, using TDM/PCM/PSK/TDMA (time division multiplex/pulse code modulation/phase shift keying/TDMA) techniques, is about 640 channels and, with digital speech

Continued on page 44

Table 2
Cost of Korean satellite system

	Investment Year	System Operation Year 1	2	3	4	5	6	7	Total over period
		$ Millions							
Capital cost									
Space Segment									
Spacecraft: 2 @ $43.3 million	86.4								
Launch: 2 @ 36.0	72.0								
Insurance	15.8								
Launch support: 2 @ $5.0 million	10.0								
SOCC: 2 @ 15.0	30.0								
On-orbit test/checkout	0.5								
Sub-Total	214.7								
Earth Segment									
10 Major City Telephone	6.6								
Data Communications	16.5								
Remote Islands	3.3								
Mobile/transportable	12.1								
Direct broadcast	3.9								
Video relay	0.3								
Sub-Total	42.7								
Total capital cost	257.4								
Operating cost									
Space Segment	-	.7	.7	.7	.7	.7	.7	.7	
Earth Segment		4.3	4.3	4.3	4.3	4.3	4.3	4.3	
Sub-Total Operating Cost		5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Total annual expenditures	257.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	292.4

interpolation (DSI) implemented, about 1280 one-way trunks can be transmitted serving the entire 10-city network. Advanced techniques can expand capacity per transponder to a one-way trunk volume of 5120. To meet this high capacity and utilize the flexibility of digital transmission, and for several other reasons, the recommended modulation and multiple-access technique is all-digital.

A fully-connected 2-meter antenna terminal employed in a mesh network has been designed for the data, remote island and mobile services. Considering both analog and digital designs, three transponders are required. The capacity of the transponders would be 2700 one-way channels, which meets the 2400-channel data requirement, using either digital or analog systems. Using demand assigned multiple access (DAMA), the mobile needs also can be met with the same three transponders. An additional transponder is assigned to the remote island network in order to keep the digital and analog traffic separate. Total need is six, but seven transponders are recommended to avoid mixing modulation types, in order to maximize power utilization and efficiency. As desired, there would be additional transponders available for alternative solutions.

For Olympic coverage, the satellite system will be used with the mobile/transportable terminals, fitted with television modems. If the five terminals regularly required are not sufficient, or if event schedules prohibit timely relocation, additional terminals could be leased, all for inward feeds to a central broadcast and program facility at Seoul. The broadcast facility can then provide Ku-band feeds to the satellite broadcast transponders for Korean national coverage, C-band feeds to the International Telecommunications Satellite Organization (INTELSAT) station for worldwide coverage, and to cable systems in Japan, and to supplemental INTELSAT feeds, as required.

Direct broadcast reception

The application of DBS power levels will permit the use of small earth terminals located at individual households and businesses. These terminals are presently under development and near production for use with DBS systems being planned or under construction in Europe, Japan and the United States. They are estimated to cost as little as $250 to produce in large quantities, and after other costs of marketing, shipping, distribution networks, installation, training and other variables, should sell for less than $500. They also may be set up for leasing in cases where possible reinstallations are still cost-effective, and when early widespread network usage is desired.

Using the recommended 0.8 meter antennas and a 4.0 dB noise figure receiver, the expected video signal-to-noise ratio will be 47.5 dB—providing a high-quality picture. The satellite system also will provide freedom from multipath "ghosting" and fading.

Access to television signals from the satellite should be excellent in Korea, because the elevation angle to the satellite will always exceed 42°. While severe rain conditions can cause fading at 12 GHz, rainfall rate statistics for Korea show a quite favorable situation for the use of this frequency; outages will be very infrequent. The signals from these earth terminal receivers would be connected to a television set's monitor input, or to a modulator to upconvert to an unused very high frequency (VHF) channel. The earth terminals are an obvious technology transfer area for manufacture within Korea.

The community broadcast receiver systems must provide slightly higher signal strength, because the rebroadcast sequence will degrade the quality somewhat. The terminals can use the same receiver, but the antenna should be a little larger. A 1.2-meter antenna is recommended. Low-power television translators or rebroadcast facilities can serve as a multiplier for the DBS programing where open television channel frequencies are available, and reception is difficult or impossible. Transmitter costs dominate, but are spread over hundreds of viewers. The relative cost for each application requires detailed study for least-cost implementation.

Costs have been estimated for the Korean satellite system, for an INTELSAT leased space segment plus Korean earth segment and for a terrestrial system which satisfies some but by no means all of the network and television requirements. Terrestrial and satellite systems are not comparable. There are satellite system telecommunications functions that are impossible to achieve with a terrestrial system, such as Korea's mobile telecommunications needs, service to remote islands and near total television coverage. Thus, while the cost for a terrestrial system appears to be less than that of a satellite system, the terrestrial system is by far inferior; indeed, it is unacceptable because it does not, and cannot, perform as required. Therefore, a low cost is meaningless. In fact, an opportunity cost should be added to the actual cost of the terrestrial facilities to account for the lost service. Korea's requirements can be effectively served only by satellite. However, costs for a terrestrial system also have been considered.

In case of a lease for an INTELSAT V 14/11 GHz east spot beam with the same EIRP as the Korean satellite, the corresponding annual charge

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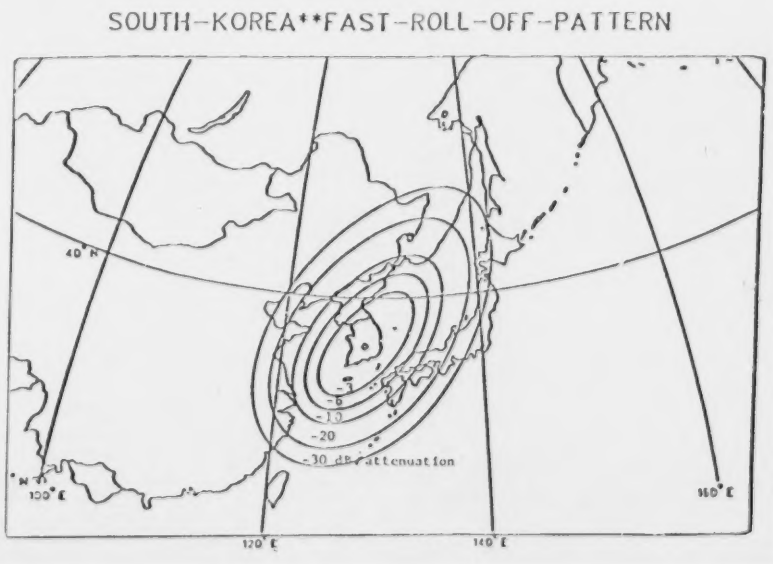
FIG. 1 *An illustration of the elliptical optimum footprint.*



'All of the Korean national coverage requirements, network requirements and direct broadcast requirements can be met using low-risk satellite and small earth terminal system designs.'

has been calculated for the number of INTELSAT (International Telecommunications Satellite Organization) lease units equivalent to the initial transponder service requirement of the Korean satellite system. The cost of the earth segment is the same in the two cases.

The proposed Korean satellite will provide a capacity of at least three times that required for the initial services desired. Therefore, for proper economic comparison with an INTELSAT lease, only one-third of the space segment cost of the Korean satellite should be attributed to the project under study. To obtain a net cost attributable to the project, it is necessary to subtract an amount proportional to the unused capacity of the space segment.

The comparison of annual expenditures (capital plus operating costs) for the three alternatives over a 7-year minimum project life is shown in Table 1. Table 2 shows the estimated cost for the Korean satellite system major elements.

In addition to its higher cost, leasing capacity from INTELSAT presents the disadvantage that Korea would not have control of the space segment; this fact will limit the use of the satellite for whatever purpose Korean authorities may wish. Sovereign use of the space segment is of the utmost importance to Korea. Therefore, an opportunity cost could be added to the INTELSAT lease which would bring the value of the leasing alternative even higher than the ownership alternative. This confirms the logical choice that the preferred alternative is for Korea to develop its own satellite system.

The economic cost comparison among the three alternatives is: Korean satellite system (one-third transponder capacity), $157.5 million; comparable INTELSAT lease, $295.4 million; and non-comparable terrestrial system (meeting only some requirements), $91.4 million. Thus, a Korean satellite system is the only viable solution for meeting the requirements.

All of the Korean national coverage area requirements, network requirements, and direct broadcast requirements can be met using low-risk satellite and small earth terminal system designs. Antenna patterns can be modified to optimize this domestic satellite system, while keeping full regard for the CCIR's power flux density and interference level requirements outside the country. If the schedule proceeds very soon, as recommended, worldwide and regional Olympic coverage requirements can be met via this satellite system when added to the central broadcast facilities and INTELSAT distribution capability. The direct and community broadcast facilities will move the nation toward 100% television reception, while providing an opportunity to join in a growing, worldwide business field.

Moreover, major significant advantages to Korea in owning and operating its own satellite system are:

- Technically, it will integrate the network and accelerate the evolution of the communications network into an all-digital national ISDN (integrated services digital network). It will also implement important alternative routings.
- It will provide remote, mobile and strategic communications, nearly total television coverage and educational television, all of which will result in economic and social development and stimulate national unity.
- It will permit total broadcasting of the 1988 Olympic Games, nationally and internationally.
- It will stimulate new product manufacturing, transfer of new technology, and advancements in research and development.
- It will provide secure circuits.
- It will provide an ideal means of coping with national emergencies through transportable and mobile units located in strategic centers of the nation.
- As an indirect benefit, it will discourage migration from previously unserved remote areas to the crowded cities while providing an incentive to develop such areas.
- It will have a favorable impact on the country's image in international circles. The capability to plan and implement such an important project will bring momentous national significance and international prestige.

The prospects for satellite communications in Korea are bright indeed. □

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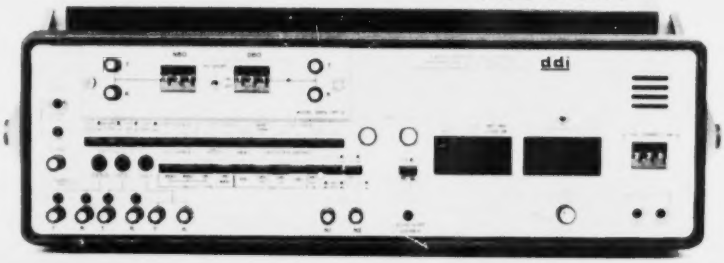

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